"RECENT DEVELOPMENT & ADVANCEMENT IN COATED CUTTING TOOL-A REVIEW"

Chandresh P. Rana [1]

[1]Asst. Professor, Mechanical Engineering Department, Vadodara Institute of Engineering, Gujarat, India

ABSTRACT

The cut throat worldwide competition in the world is forcing the manufacturing industry to re-evaluate their existing operational and technological capability. Since most recent couple of years, quick changing innovations technologies on the product front advised the requirement for an equally fast response from the industries to meet the challenges, industries have to focused on the achievement of extreme quality of work piece, surface finishing, dimensional accuracy, high production rate, less wear on the cutting tools and in the term of economy of the cost saving.

As we probably aware the cutting tool is an important basic tool required in metal removal operations for producing the components. The longer life of the cutting tool depends on various parameters like machine tools utilized for the machining operation, cutting conditions, work piece material. Therefore, for the development and introduction of new coated cutting tool, it is necessary to carry out a number of studies with the purpose to optimize the coatings composition. The Present Review work is based on Recent Development and Advancement in Coated Cutting Tools, in which comparing different methods of coating like PVD & CVD and also looking at different coating Materials like TiN, TiAlN, TiCN, TiC, CrN, ZrN, TiB_2 etc.

Keyword – *Coated Cutting Toil, PVD, CVD, TiN, TiAlN, TiCN, TiC , CrN, ZrN, TiB_2*

1. INTRODUCTION

In the context of machining, a cutting tool or cutter is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, planning and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run. Cutting tools must simultaneously withstand big mechanical loads and high temperatures. Temperature in the chip/tool interface reaches more than 700 °C in some cases.

Cutting Tool Materials

I. Carbon steel
II. High speed steel (HSS)
III. Cemented carbide
IV. Ceramics
V. Diamond
VI. Cubic boron nitride (CBN)

Different machining applications require different cutting tool materials. The ideal cutting tool material should have all of the following characteristics:

- Harder than the work it is cutting
- High temperature stability
- Resists wear and thermal shock
- Impact resistant
- Chemically inert to the work material and cutting fluid
- Tool material must be at least 30 to 50% harder than the work piece material..
- High toughness
- High thermal conductivity
- Lower coefficient of friction

Needs and Development of Cutting Tool Materials

With the progress of the industrial world it has been needed to continuously develop and improve the cutting tool materials and geometry:

- To meet the growing demands for high productivity, quality and economy of machining
- For precision and ultra-precision machining
- The cutting tool materials
- The cutting tool geometry
- Proper selection and use of those tools
- The machining conditions and the environments out of which the tool material plays the most vital role.

Table No:-1
Different element used in cutting tool materials and their properties

Materials	Properties
Tungsten	Increases hot hardness; Hard carbides formed; Abrasion resistance
Molybdenum	Increases hot hardness; Hard carbides formed; Improving resistance
Chromium	Depth hardenability ; Improving abrasion resistance; Some corrosion resistance
Vanadium	Combines with carbon for wear resistance; Retards grain growth for better toughness
Cobalt	Increases hot hardness, toughness
Carbon	Hardening element forms carbides

The right surface treatment on small round tools can increase overall life, decrease cycle time and promote better surface finishes. Unfortunately, choosing the right coating for your high production application can be a confusing and arduous task. Each one has advantages and disadvantages in the machining process.

There is a vast selection of PVD (Physical Vapor Deposition), CVD (Chemical Vapor Deposition) and alternate surface treatments that are readily available from your manufacturers or coating facilities. There is different coating Materials like TiN, TiAlN, TiCN, TiC, CrN etc. For better performance we have optimize to the proper cutting tool materials, coating materials with application of proper coating methods.

2. LITERATURE SURVEY

(1) R. Porat – 1991[1]

He has found that a thin layer with a CVD process of ceramic material, Applying A1203 on silicon nitride based material for machining cast iron can help to increase the tool life of cutting tool materials. Cutting Tools coated with A1203 CVD can machine cast iron successfully with an economic tool life at a speed of 900 m/min. Coated A1203 on Ceramic materials, which are composed especially for machining steel, will not improve tool life since it behaves like pure solid aluminum oxide cutting tools.

(2) Shanyong Zhang ,Weiguang Zhu - 1993 [2]

He conclude from this research paper that Titanium nitride coated of tool steel is proven to way of success in high boost in production and curtailing cost. PVD process are more appropriate compare to CVD process in term of HSS.

(3) Anakkavur T. Santhanam - July 1994 [3]

In this Patent he conclude that at least one CVD layer is included in coating having a residual compression stress. The cutting tool has been found useful while machining of titanium alloys and super alloys.

(4)Deepak Bhatt – September 1995 [4]

In this Research, Author was discuss the design and development of chemical-vapor-deposited (CVD) TiCN/TiN multilayer coatings applied to a WC-12% Co tool substrate. The performance of the coated tool is compared with à conventional tool coated with a single, monolithic CVD TiN layer, and it is shown that a judicious combination of coating compositions can be tailored to meet the operating requirements.

(5)T. Krieg - 1999 [5]

It is Clear from this research paper that Innovations such as the application of advanced work material concepts, together with needs for non-pollutant machining processes, increased flexibility and improved cost-effectiveness trigger the application of high performance processes. This often reveals inadequate wear resistance in conventional tool materials. This inadequate wear resistance can be protected from the failure of the tool. Also the cutting speed of the metal cutting was too higher and accurate compare to simple coated or else un-coated tools. TiN performs better cutting rate and feed.

(6)Devi P. Saini; M Ali – 2003 [6]

In this research, authors say that PVD coatings of several novel architectures were applied on cemented carbide inserts and tested at high cutting speeds in turning operations. The thickness of the coatings was observed to influence the coating adhesion as well as tool life at high turning speeds. TiC coating was found to provide the longest tool life. The multilayer composite coating Ti, TiN, TiCN, TiC showed good promise for high speed turning operations.

(7)E. Uhlmann, E.Wiemann, S. Yang, J. Krumeich, A. Layyous – 2005 [7]

They state that, In the machining of different workpiece materials with new Cr-based and ceramic tool coatings, they found that, in turning tests under with the use of a coolant lubrication, the new Cr-based coatings CrTiAlN and CrMoTiAlN showed almost always the lowest width of wear land of all tested coatings. The highest improvement compared to a TiAlN reference coating was accomplished in the machining of a chrome-cobalt alloy, where the measured wear could be reduced by more than 60 %.

(8) M. Sokovic, J. Kopac, L.A. Dobrzanski, J. Mikula, K. Golombek, D. Pakula – 2006 [8]

Researchers conclude that Employment of the hard anti-wear coatings deposited onto the sintered ceramic tool inserts with the physical deposition from the gaseous phase (PVD) is reckoned as one of the most important achievements in the last years in the area of improvement of the service properties of ceramic cutting tools. It possible to achieve the clear improvement of their tool life and also of the quality of the machined surfaces, reduction of machining costs and elimination of cutting fluids used in machining.

(9) T. Cselle, O. Coddet, C. Galamand, P. Holubar, M.Jilek, J. Jilek, A. Luemkemann, M.Morstein – 2008 [9]

They summarizes that the most important material components and their influence on the features of the coatings. Carbon strengthens the lattices of the basic coating TiN, increases the internal stress level and therefore the hardness, reduces the friction coefficient, but only up to 400°C. The TiCN coating is still the most popular coating for taps but is not adequate for dry and high-speed cutting. Due to the excellent heat insulation between chips and tools, the TiAlN or AlTiN coatings are the most used coatings for modern high performance cutting.

(10) B. Ramamoorthy et al.[10]

He state that The sputter deposition conditions for DLC/TiN/ Ti/Cu/Ni multilayer coatings are identified to achieve improved quality with particular reference to adhesion and surface finish.

(11)Yaha Isiq– October -2010 [11]

He give discussion of the properties, and performance of coated tools and tool coatings was presented. Single-layered PVD coated TiAlN and multi-layered CVD coated TiC + TiCN + TiN, TiC + AI2O3 + TiN, TiN + TiCN + TiN cutting inserts were, observed that amongst all wear types, flank wear was the most frequently encountered.

(12) Yahya Isik – 2010 [12]

He investigates that An Experimental Investigation on Effect of Cutting Fluids in Turning with Coated Carbides Tool .He conclude that CVD coated carbide TiC+AI2O3+TiN cutting tool performed better during wet machining mode.

(13)Titus .B. Watmon and Anthony .C. Ijeh – 2010 [13]

There is conclusive evidence to say that coating with hard substances like TiN, TiC and Al203 improves cutting tool capabilities. The wear resistance of the coating itself should be superior to that of the substrate. The coating lowers the friction coefficient and thereby the contact temperature. The coating acts as a heat barrier owing to the lower thermal conductivity compared with that of the substrate. The coating has lubricating properties because it can generate secondary layers in the wear surface,

(14) Mr. Mahesh. J. Patil – 2010 [14]

He conclude that the wear rate of uncoated carbide tools was faster than coated carbide tools. At low feed rate of 0.05 mm/rev, the flank wear was uniformly formed on the cutting edge at slow wear rate. Ra values of uncoated and coated carbide were in range of 0.36-0.45 urn and 0.3-1.15 urn respectively. The optimum surface roughness value of coated card ideal tool was obtained at cutting speed of 250m/min and feed rate of 0.05 mm/rev.

(15)Y. C. Chim1 et al. – 2010 [15]

He states that TiN, CrN, TiAlN and CrAlN coatings were deposited by vacuum arc. Their thermal stability and oxidation resistance were investigated after annealing in air at different temperatures (500°C-1000°C). TiAlN and CrAlN showed better oxidation resistance than their binary counter parts TiN and CrN. Cr-based coatings exhibited much better oxidation resistance than Ti-based coatings.

(16) M. Kaladhar , K. VenkataSubbaiah, Ch. Srinivasa Rao – 2011 [16]

They conclude that the best surface finish of AISI 304 is obtained for cutting by insert coated with TiAlN-TiN by PVD technique. Cutting speed (37.83%) is the significant factor when the material is turned by CVD insert. The optimal combination of process parameters for obtaining minimum surface roughness values at 190 m/min cutting speed, 0.25 mm/rev feed, 0.5 mm depth of cut and 0.4 mm nose radius when turning with CVD insert. The optimal combination of process parameters for obtaining minimum surface roughness values at 170 m/min cutting speed, 0.25 mm/rev feed, 1.00 mm depth of cut and 0.4 mm nose radius when turning with PVD insert.

(17)Natalia L. Cadena, Rodrigo Cue-Sampedro, Héctor R. Siller, Ana M. Arizmendi-Morquecho , Carlos I. Rivera-Solorio and Santiago Di-Nardo - 2013 [17]

They summarizes that the AlCrN-T coating presented low friction coefficients and wear rates tested by pin-on-disk, in comparison with previous works.It was revealed that the AlCrN-T coating has a wide potential tribological application under the condition of sliding wear. The machinability study with the coated carbide tool and a workpiece of titanium alloy, presented improved results and the viability of other novel coatings (multi-layer) with similar constitutive and heat-treated materials.

(18)Abrar A. Arshi, Atish Dighewar – 2013 [18]

He conclude that the Tin coated tool perform better as compared to uncoated cutting tool. The effect of cutting is to reduce wear and tear of tool tip point as well as more heat dissipation to surrounding hence the increase in tool life and surface finish of the product to be machine. With increase in depth of cut the surface roughness is increased.

(19) Deepak Mehra , KhushwantRakhecha – 2013[19]

He makes Comparison of TiN coated insert with Uncoated Carbide tip on the basis of Power consumption, coefficient of friction, depth of cut and cutting forces by setting different cutting parameters. Analysis of cutting forces via both uncoated and coated tool. And the tool considered was single layer coated tool and multi-layer coatings on cutting tool performance. Multi layers are believed to offer very high strength, hardness, heat resistance, and many new properties that could greatly enhance the performance of the cutting tools.

(20) M. Narasimha, R.Reiji Kumar, Achamyelehaemro Kassie – 2013[20]

They conclude that the machining performance of five cutting tool inserts in turning AISI 1018 steel. Uncoated, TiN coated, TiN/Al2O3 coated, Al2O3 coated and TiC/Al2O3/TiN coated tools were examined and their flank wear and the resultant machined work piece surface finish were analyzed. The wear of the TiN coated tool was around 12% lower than the wear observed on the uncoated tool. TiN/Al2O3 coated tool showed a decrease of around 65% compared to the uncoated tool. The Al2O3 coated tool showed a decrease of around 92% compared to the uncoated tool.

(21)Saravanan Lakshmanan, M. Anthony Xavior – 2014 [21]

Authors say that the relationship between the input and output parameters has been established for intermittent cut of AISI 1030 steel. They state that Coated tool produces better surface finish at higher cutting speeds, but the tool wear rate is very rapid. Dominant tool wear is at flank face and the abrasion is the wear type. Uncoated inserts performs better at moderate rate cutting speeds comparing to coated inserts, but at higher cutting speeds the tool experienced maximum flank wear. The frequency of intermittent cut increases as the cutting speed increases which is the major reason for this.

(22)M.Narasimha, Mahaboob Patel, R.Rejikumar – 2014 [22]

From their research work, They summarizes, During the machining of hardened M42 tool steel, TiAlCrYN coatings are effective at reducing tool wear due to chipping and tend to improve tool life. They try to show the importance of improvement of cutting tool performance by PVD or CVD coatings.

(23)A.Thakur, S.Gangopadhyay, A. Mohanty, K.P.Maity – 2014 [23]

Theresearch work investigated the effect of cutting speed and tool coating on chip characteristics and tool wear during dry machining of Nimonic C-263.

The multilayer coating consisting of TiN/TiCN/Al2O3/ZrCN plays a major role in improving resistance to wear particularly at higher cutting velocity. From results it can be concluded that uncoated tool ISO P30 grade is not recommended for cutting speed higher than 51 m/min, whereas CVD multilayer coated inserts performed well within the range of cutting speed of 51-84 m/min with constant feed of 0.2 mm/rev and depth of cut of 1 mm.

(24)Pratik L. Nagalwade, A. V. Kale -2014 [24]

Based on the experimental results presented and discussed, the following conclusions are drawn on the effect of cutting speed and feed on the performance of TiN coated and uncoated carbide tools when turning AISI 4140 steel.

The forces over coated inserts are less than the uncoated inserts which results in less amount of stress over coated inserts than uncoated inserts. Coated carbide tools perform better than uncoated carbide tools as far as tool life is concerned. This study concluded that the TiN coated carbide tool produce better surface roughness with respect to high speed and low feed rate.

(25)N. Balasubramanyam1, Smt. G. Prasanthi and M. Yugandhar – 2015 [25]

In this research work they had Study of Coated TiN and TiC on Cutting Tools for the PVD and CVD Coated Tungsten Carbide by Sand Blasting Pretreatment of Nickel and Carbon

The AlCrN-T coating deposited by the PVD process showed physical properties with a wide range of applications for manufacture. The structural analysis shows that the heat treatment of AlCrN coating allows recrystallization and crystal growth, enhancing its wear behavior. It was revealed that the AlCrN-T coating has a wide potential tribological application under the condition of sliding wear. It was fully demonstrated that an AlCrN-T coating can be used with acceptable levels of productivity in the machining of aerospace and biomedical components.

(26)Shreedhar Bhattarai – 2015 [26]

He Conclude, Nickel coated and Zinc coated tool individually under provided feed, speed and depth of cut. Temperature released during machining of aluminum by zinc coated tool was high compared to uncoated and nickel coated tool. Zinc coated tool produced rough surface compared to uncoated tool but nickel coated tool produced fine surface finish. From heat generation and surface finish aspect nickel can be considered as a good metal for cutting tool coating.

(27)Suraj R. Jadhav, Aamir M. Shaikh – 2015 [27]

This work considered some ways to improving cutting tool life by means of coating method. The performance of coated cutting tool is better than the conventional cutting tool. Tool coating improves properties of cutting tool such as surface roughness, Chemical stability, anti-welding and anti-diffusivity, thermal conductivity, Surface lubricity and anti-seizure. Coated tool also suitable for various cutting conditions such as cutting velocity, feed rate and depth of cut. Tungsten Carbide coated cutting tool cuts about 3 to 5 times faster than conventional cutting tools.

(28)Yeshwanth Reddy Chandrashekar Reddy – 2015 [28]

It was found that It's seen that dry machining has seen a positive trend in its use and applications in machining the tougher materials. However the importance of lubricants is vital for overall success of a machining operation and solid lubricants need to improve more on this regard. Challenges in adhesion of the coating and distribution of the coating is seen to govern the life of the tool as shown in machining of AISI 4340 steel where the presence of lubricant reservoirs didn't show a decrease in certain categories of tool wear. Though most of the tools with lubricant coatings gave satisfactory surface quality for a limited period of machining time, wet lubrication is still unmatched in terms of surface finish.

(29) B. Vasques, A. Bouchou, R. Leroy, N. Ranganathan, P. Donnadieu – 2016 [29]

They state that In order to study the evolution of the nano-mechanical properties with the temperature, nano-indentation tests were made on a CVD and a PVD coated inserts at different temperatures. Nano-indentation is sensitive to the surface roughness; subsequently a 200 mN load was required to perform an acceptable penetration depth in order to determine the global mechanical properties by indentation. The PVD coated insert maintain his properties when temperature is increasing in comparison to the CVD coating. Cutting temperatures can range 800 - 1000°C. In perspective, investigation of these materials until 800°C will be performed to predict real behavior under machining conditions.

(30)Haruyo Fukui – 2016 [30]

He says that in the 1970s, the CVD process combined with dedicated carbide substrates performed well as a forerunner in commercializing coated inserts. Subsequently, the PVD process came into use in a wider range of applications along with the widespread use of arc ion plating in the 1990s. Since then, both processes have evolved greatly. Currently, it is increasingly important to select suitable insert materials according to the intended use.

3. CONCLUSION

From the literature review of Recent Development and Advancement in Coated Cutting Tools, review work investigated the following conclusions:

1. Coating tool helps to increase surface finish of the work piece, tool life and production rate. It is found that tool wear also getting very low compare with uncoated cutting tool.
2. If we require the coating on High Speed Steel, the PVD process are more appropriate compare to CVD process. TiCN coating is ideal for HSS cutting tools.
3. CVD coating is good for the Ceramic Tools.
4. A Diamond coating with a CVD process that offers the highest performance available in non-ferrous materials. Ideal for cutting graphite, MMC (Metal Matrix Composites), high silicon aluminum and many other abrasive materials.
5. All the coating materials are perform better but the selection of the appropriate coating materials is depend on the work piece materials and cutting conditions.
6. We have improve the properties of cutting tools like Hardness, Wear Resistance, Surface Lubricity and anti-Seizure with coating.
7. In development of this Coating materials hardness is also gradually increase of TiN (21 Gpa) to Diamond (88-98 Gpa).

4. REFERENCES

1. R. Porat, “Cvd Coating Of Ceramic Layers On Ceramic Cutting Tool Materials” Journal De Physique Iv Colloque, 1991, 02 (C2), Pp.C2-549-C2-556.
2. Shanyong Zhang , Weiguang Zhu , “Journal Of Materials Processing Technology”, 39 (1993) 165-177, Elsevier.
3. Anakkavur T. Santhanam “Method Of Machining Coated Cutting Tool” July-1994
4. Deepak Bhatt “Development Of A Graded Ticn Coating For Cemented Carbide Cutting Tools-A Design Approach” September 1995, Elsevier
5. T. Krieg “Coated Tools For Metal Cutting – Features And Applications” 1999,Elsevier
6. Saini, D. P. & Ali, M., “New Generation Coatings For High Speed Cutting Tools”, Icme 9th International Conference On Manufacturing Excellence 2003 (Pp. 1-12). Australia Instiution Of Engineers.
7. E. Uhlmann, E.Wiemann, S. Yang, J. Krumeich, A. Layyous , “Newcoating Developments For High Performance Cutting Tools” -2005
8. M. Sokovic, J. Kopac, L.A. Dobrzanski,J. Mikula, K. Golombek, D. Pakula, “Cutting Characteristics Of Pvd And Cvd - Coated Ceramic Tool Inserts”-2006
9. T. Cselle1, O. Coddet1, C. Galamand1, P. Holubar, M. Jilek, J. Jilek, A. Luemkemann1, M. Morstein, Journal Of Machine Manufacturing Received: 26th October 2008, Accepted: 20th December 2008
10. B. Ramamoorthy, Binu C. Yeldose Intelligent Information Management, 2009, 1, 179-194
11. Yahya Isik, “Tool Life And Performance Comparison Of Coated Tools In Metal Cutting”-International Journal Of Materials And Product Technology ,October 2010
12. Yahya Isik, “Journal Of Mechanical Engineering” 56 – 2010
13. Titus .B. Watmon And Anthony .C. Ijeh, “Coating Cutting Tools With Hard Substance Lowers Friction Co-Efficient And Improves Tool Life - A Review” Proceeding Of The International Multi Conference Of Engineers And Computer Scientists 2010 Vol Iii, Imecs 200, March 17-19,2010,Hong Kong
14. Mr. Mahesh. J. Patil, “Investigation In Tool Life Of Coated And Uncoated Carbide Tools In Turning” 2nd National Conference Time 2010

15. Y. C. Chim1, X. Z. Ding, X. T. Zeng, And S. Zhang1 Simtech Technical Reports (Str_V11_N2_04_Stg) Volume 11 Number 2 Apr-Jun 2010
16. M. Kaladhar , K. Venkata Subbaiah, Ch. Srinivasa Rao, "Performance Evaluation Of Coating Materials And Process Parameters Optimization For Surface Quality During Turning Of Aisi 304 Austenitic Stainless Steel"- International Journal Of Engineering, Science And Technology,Vol. 3, No. 4, Pp. 89-102,2011
17. Natalia L. Cadena, Rodrigo Cue-Sampedro, Héctor R. Siller, Ana M. Arizmendi-Morquecho , Carlos I. Rivera-Solorio And Santiago Di-Nardo, "Study Of Pvd Alcrn Coating For Reducing Carbide Cutting Tool Deterioration In The Machining Of Titanium Alloys"- Articles Of Materials Journal, 6, 2143-2154; Doi:10.3390/Ma6062143, 2013
18. Abrar A. Arshi, Atish Dighewar, "Study And Analysis Of Effect Of Coating On Hss Cutting Tool A Review Paper" International Journal Of Science, Engineering And Technology Research (Ijsetr) Volume 2, Issue 4, April 2013
19. Deepak Mehra, "Comparison Of Mechanical Properties And Calculation Of Cutting Force Between Uncoated Tungsten Carbide & Ti Coated Tip Tungsten Carbide With The Help Of Lathe Tool Dynamometer" International Conference On Ceramics, Bikaner, India International Journal Of Modern Physics: Conference Series Vol. 22, Pp 645–653, 2013
20. M. Narasimha1,R. Reiji Kumar2, Achamyelehaemro Kassie, " Performance Of Coated Carbide Tools"- The International Journal Of Engineering And Science (Ijes),Volume-2,Issue-6,Pages 47-54, 2013
21. Saravanan Lakshmanan, M. Anthony Xavior, " Performance Of Coated And Uncoated Inserts During Intermittent Cut Milling Of Aisi 1030 Steel" 12th Global Congress On Manufacturing And Management, Gcmm 2014,Elsevier
22. M.Narasimha, Mahaboob Patel, R.Rejikumar, "Application Of Coating On Carbide Insert", The International Journal Of Engineering And Science (Ijes) Volume-3,Issue- 4 ,Pages-01-07 ,2014
23. A.Thakur, S.Gangopadhyay, A. Mohanty, K.P.Maity, "Performance Evaluation Of Cvd Multilayer Coating On Tool Wear Characteristics During Dry Machining Of Nimonic C-263", 5th International & 26th All India Manufacturing Technology, Design And Research Conference (Aimtdr 2014) December 12th–14th, 2014,IIT Guwahati, Assam, India124-1
24. Pratik L. Nagalwade1*, A. V. Kale2 Performance Evaluation Of Tin Coated And Uncoated Carbide Tools In Turning Aisi 4140 Steel, 5th International & 26th All India Manufacturing Technology, Design And Research Conference (Aimtdr 2014) December 12th–14th,Iit Guwahati, Assam, India, 2014
25. N. Balasubramanyam, Smt. G. Prasanthi And M. Yugandhar, "Study Of Coated Tin And Tic On Cutting Tools For The Pvd And Cvd Coated Tungsten Carbide By Sand Blasting Pretreatment Of Nickel And Carbon", International Journal Of Advanced Science And Technology Vol.75, Pp.51-58, 2015
26. Shreedhar Bhattarai, "Performance Analysis Of Coated Single Point Cutting Tool In Turning Operation", (I Jitr) International Journal Of Innovative Technology And Research,Volume No.3, I Ssue No.4, June - July 2015, 2234 – 2243. 2320 –5547
27. Suraj R. Jadhav, Aamir M. Shaikh, "Study & Performance Of Coated Cutting Tool", International Journal Of Engineering, Business And Enterprise Applications,Reserved Page 99, 2015
28. Yeshwanth Reddy Chandrashekar Reddy, "Application Methods And Performance Study Of Coatings On Tools Used In Dry Machining", International Research Journal Of Engineering And Technology (IRJET)Volume -02 Issue-04, Page 542 July-2015
29. B. Vasques, A. Bouchou, R. Leroy, N. Ranganathan, P. Donnadieu, "Carbide Coated Cutting-Tool Properties Investigation By Nano-Indentation Measurements Under 260-460°C" -2016
30. Haruyo Fukui, "Evolutional History Of Coating Technologies For Cemented Carbide Inserts- Chemical Vapor Deposition And Physical Vapor Deposition" 2016